

Adjunctive Treatment of Enchondromas With CO₂ Laser

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Study Design/Materials and Methods: Fourteen enchondromas, in eight patients, involving the tubular bones of the hand, were treated with curettage, CO₂ laser sterilization of the tumor margins followed by autologous bone grafting. Average follow-up time was 35.4 months (14–106 months). Average patients age was 29 years.

Results: At follow-up there were no clinical recurrences, none had pain, and all patients reported satisfactory hand function without limitations. Minimal decrease in range of motion without functional limitation was encountered following excision of two lesions (14%) in one patient. One patient reported an increase in range of motion after excision. Grip strength was only minimally decreased. There was no radiographic evidence of recurrence.

Conclusion: The use of CO₂ laser is safe and effective as an adjunct to curettage and bone grafting in the management of relatively large enchondromas of the tubular bones of the hand. *Lasers Surg. Med.* 24:187–193, 1999. © 1999 Wiley-Liss, Inc.

Key words: CO₂ laser; enchondromas; tubular bones

INTRODUCTION

Enchondromas are benign cartilaginous tumors and are the most common primary bone tumors in the hand representing 90% of all such tumors [8,11–18]. Forty-five percent of all enchondromas are located in the short tubular bones of the hand. Enchondromas are often discovered incidentally on radiographs. They are usually asymptomatic but sometimes present with mild pain or as a pathologic fracture. Malignant transformation of enchondroma to chondrosarcoma may occur especially in patients with multiple lesions. However, in the hand, most solitary enchondromas remain benign and rarely undergo malignant transformation [1,19,20] which occurs in less than 1% of the cases [7,22].

Management of enchondromas vary from observation of asymptomatic lesions to surgery. Surgical treatment is usually reserved for patients with a healed pathologic fracture, delayed union, suspicion of malignant transformation, or those with persistent symptoms of pain and swelling [3,23]. Surgical treatment of enchondromas is

controversial and may range from curettage with or without bone grafting to en-bloc resection and bone grafting. The most frequently utilized surgical treatment is curettage and bone grafting. A potential problem with this management option is that a zone of viable tumor up to 1–3 mm in depth can persist in the tumor bed after curettage [24]. Recurrence rates reported in the literature after curettage and bone grafting range from 2–15% overall. This has lead many investigators to search for means to “sterilize” the tumor bed after curettage in an attempt to decrease recurrence rates. Reported adjunctive treatments used in the management of enchondromas include chemical cauterization with phenol or alcohol, heat cauterization with polymethylmethacrylate, freezing with liquid nitrogen, and cryotherapy. These adjunctive methods have decreased the recurrence

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rate, but at the expense of other serious complications such as wound healing problems due to unnecessary tissue damage, infections, and fractures.

The purpose of this study was to investigate the efficacy and safety of the CO₂ laser as an adjunctive treatment for enchondromas following curettage and subsequent autologous bone grafting. The functional outcome of this patient group was also evaluated after this treatment protocol.

MATERIALS AND METHODS

Over a 9-year period, 17 symptomatic enchondromas in 10 patients were treated by the senior surgeon (GMR) with curettage, CO₂ laser tumor margin sterilization, and autologous bone grafting. Inclusion criteria for our study required a minimum of 12 months follow-up from surgical treatment and a follow-up visit for physical examination, subjective functional outcome questionnaire, and radiographs of the operated hand. We were unable to locate two of the patients and therefore excluded them from the study, one with a solitary lesion and the other with two lesions, leaving eight patients and 14 lesions for review.

All patients were evaluated by two of us (DWG and SJM) during the recent follow-up. The physical examination encompassed evaluating the digital joints range of motion, grip strength, palpation of the operative site for evidence of recurrent lesions or tenderness, scar appearance, and functional outcome. Comparisons were made to the contralateral normal hand.

Joint range of motion was measured proximal and distal to the involved bone with a digital goniometer and compared to the non-operated control hand. Grip strength was measured with a standard Jamar dynamometer and was also compared to the non-operated hand. The difference was corrected for the normal variance of dominance. The operative areas and scars were evaluated with inspection and palpation.

The subjective functional outcome questionnaire included a list of 10 items to be answered by the patients. There were two main categories, activities of daily living and recreational activities, each with five questions. The patient was asked to provide a graded response to each question as 1 (25% of normal), 2 (50%), 3 (75%), or 4 (100%). The graded responses for all 10 questions were then added to determine the patient's subjective functional outcome score. The maximum perfect score is 40 points.

Postoperative complications were documented by reviewing the medical records, interviewing, and examining the patients.

We assessed through the operating room billing system the additional cost for using the CO₂ laser. The laser coordinator and billing office provided the necessary information.

SURGICAL PROCEDURE

The three pathologic fractures were allowed to heal prior to surgery. The standard approach was through a longitudinal dorsolateral incision. The extensor retinaculum was retracted. The tumor area was then visualized. All enchondromas were curetted after making a cortical window over the lesion. Care was taken to prevent tumor cell contamination of the soft tissues at the surgical site. Careful and thorough curettage of the tumor bed was performed. Laser precautions were taken and the tumor bed was sterilized with the CO₂ laser using a defocused, 3 mm spot size, superpulsed mode and 5–10 watts voltage. CO₂ laser treatment was followed by autologous bone grafting, which was harvested immediately prior to tumor exposure. The wounds were closed and a splint was applied. Range of motion exercises were implemented 3–4 weeks after surgery. Immobilization was discontinued when radiographic evidence of healing was observed.

RESULTS

Seventeen enchondromas in 10 patients were treated by the senior surgeon (GMR) over the past nine years. Three lesions in two patients were excluded because we were unable to locate these patients. Therefore, we reviewed the medical records, examined, and obtained x-rays on eight patients with 14 lesions. Patients were evaluated at an average follow-up of 35.4 months (14–106 months) postoperatively.

Demographics

Average age of the patients was 29 years (6–47 years old). There were two male and six female patients (1 : 3 ratio). Six lesions were on the left side and eight on the right. Three lesions (21%) presented as pathologic fractures, 10 (71%) as palpable bothersome masses, and two (14%) as painful lesions without fracture. None were discovered incidentally. Six lesions were treated in one patient with Ollier's disease. Another patient had two lesions treated, but did not have multiple en-

chondromatosis. The remainder of the patients had solitary lesions. The number and location of the lesions were as follows: two (14%) in the small finger metacarpal, two in the small finger proximal phalanx, one (7%) in the middle phalanx of the small finger, three (21%) in the proximal phalanx of the ring finger, two in the middle phalanx of the ring finger, one in each of the index finger metacarpal, proximal phalanx and the middle phalanx, and one in the base of the thumb metacarpal.

Objective Results

Only two of 14 lesions had a decreased range of motion after excision. The range of motion in the metacarpophalangeal and interphalangeal joints of the thumb following treatment of the proximal phalanx lesion decreased by 10 and 15 degrees respectively. The second lesion was excised from the ring finger middle phalanx in the same patient who had a decreased range of motion of 15 degrees at the proximal interphalangeal joint and 50 degrees at the distal interphalangeal joint. Range of motion actually increased by 15 degrees at both the metacarpophalangeal and proximal interphalangeal joints around a lesion excised from the ring finger proximal phalanx. Assessment of the range of motion in the remainder of the joints proximal and distal to the excised lesions was noted to be equivalent to that of the normal hand.

After adjustment for dominance, grip strength was only minimally decreased by an average of 2 Kg. (0–14 Kg.) when compared to the contralateral normal hand.

There were no areas of tenderness or palpable masses in the operated sites of the 14 lesions.

Final radiographic evaluation at the most recent follow-up did not show any radiographic evidence of recurrence (Fig. 1, 2).

Subjective Results

Functional outcome was evaluated during the patient interview. The preoperative score was 30.4/40 which decreased to only 29.8/40 postoperatively. The patient with Ollier's disease was the only patient that stated he had noticed a decrease in his function since surgery due to a minimal decrease in range of motion. The remainder of the patients had full function in the operative hand and returned to the same physical activities, both work and recreational, as before surgery without any limitations.

None of the patients were displeased with the appearance of their hand or the scar at follow-up.

Laser Related Expenditures

With the appropriate precautions and protective eye wear, the operative staff did not encounter any injuries and there were no fires during laser use in any of the cases. No complications were encountered in any of the patients.

There were no surgeon's fees for the use of the laser. The operating facilities additional cost is broken down into the duration of time the laser is used in addition to the disposable equipment required. A base fee of \$116.00 for the CO₂ hand piece and the smoke evacuator was charged for each case. Fees according to the amount of time the laser was used are as follows: first 15 minutes: \$299.46, for 30 minutes: \$306.68. Additional time added to the surgical procedure for the use of the adjunctive CO₂ laser did not exceed 12 minutes. The average total cost for the laser use was \$415.46 per case.

DISCUSSION

Enchondromas represent 90% of primary bone tumors of the hand [8,11–18] and 30% of all tumors in the hand [2]. The most common locations in order of frequency are: finger phalanges, metacarpals, humerus, femur, toe phalanges, metatarsals, tibia, fibula, and ulna [7,25]. Enchondromas consist of benign lobulated masses of hyaline cartilage originating in the medullary cavity. They are probably due to failure of portions of the physeal plate to ossify resulting in proliferation of mature cartilage in the medullary canal of the metaphyseal and diaphyseal regions of bone.

The age of onset is from 10–40 years with equal male to female ratio. The lesion may be single, multiple, or part of a generalized dysplastic process. Tumor growth is usually slow during childhood and the lesions usually remain static after skeletal maturity. Enchondromas are usually asymptomatic but may present as painful lesions or pathologic fractures. One should consider a pathologic fracture, soft tissue compression, or malignant conversion if an enchondroma presents as a painful lesion [7,25,26].

Radiographic findings of enchondromas are often so characteristic that often a biopsy is not performed. These include cystic, radiolucent, expansile lesions located in the metaphysis and ex-

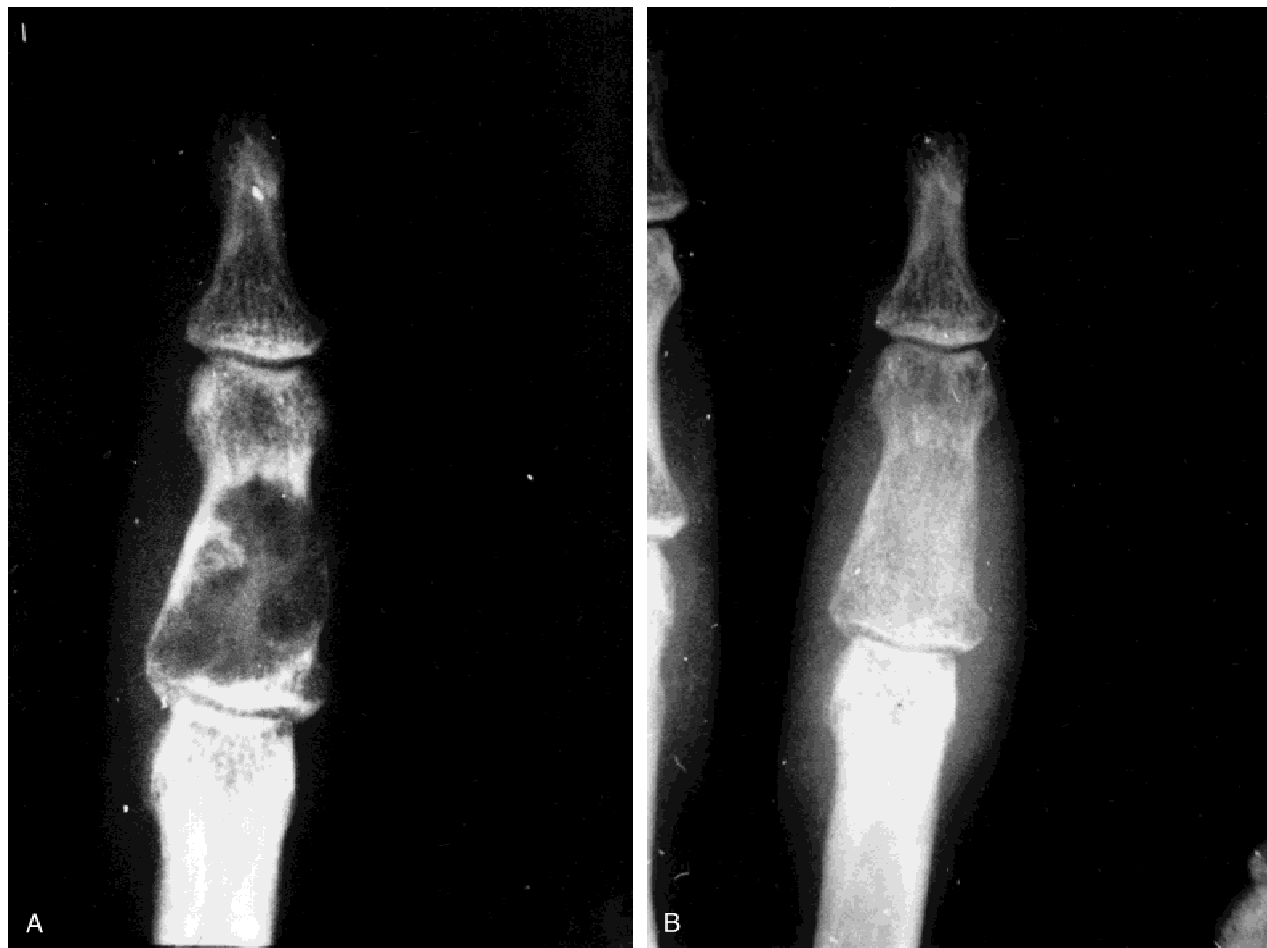


Fig. 1. **A:** A 38-year old female presented with painful swelling in the index finger. X-rays showed a multiloculated lytic lesion involving the metaphysis and diaphysis of the middle phalanx. The cortex on one side is ballooned-out, very thin and expanded. **B:** Following curettage CO₂ Laser treatment and bone grafting the patient's symptoms resolved. X-rays at follow-up showed incorporation of the bone graft and no evidence of tumor recurrence.

tend towards the shaft and the epiphysis. A sharp demarcation zone between the lesion and surrounding bone is usually seen. The matrix can calcify in a distinctive uniform punctate or stippled pattern that gives the lesion a ground-glass appearance. This radiographic appearance may be similar to that of fibrous dysplasia, but this tumor is rare in the bones of the hand. The calcific deposits within the radiolucent area that are seen in enchondromas are rarely observed in chondrosarcomas or other malignant tumors of the hand [3,27].

The histologic appearance of growing cartilage tumors, both benign and malignant, is relatively hypercellular. Enchondromas have chondrocytes residing in lacunae and appear as disorganized hyaline cartilage with myxomatous matrix that is divided into lobules separated by fibroconnective tissue septa. Cellularity ranges

from prominent as in active lesions in children to acellular with heavily calcified matrix in latent adult tumors. Atypical cells are seen in malignant tumors with frequent mitotic figures, vascular invasion, and large areas of necrosis. Frequent double nuclei in a single lacunae, hypercellular areas with little or no matrix, and mitotic figures are suggestive of malignancy. Fortunately, in the hand, malignant transformation of solitary enchondromas is very rare.

Malignant transformation occurs in less than 1% in solitary lesions, 20% in lesions associated with Maffucci's syndrome, and 50% in lesions associated with Ollier's disease [7,22]. Symptoms suggesting malignant transformation include pain in a previously asymptomatic lesion and rapid increase in size of the tumor. Recurrence of a lesion previously diagnosed as enchondroma is suggestive of malignancy [6,21]. Defini-



Fig. 2. **A:** A 31-year old female presented with severe pain and swelling of the thumb following minor trauma to the hand. X-rays showed a pathologic fracture through a lytic lesion involving the base of the thumb metacarpal. Spotty calcification can be seen within the lesion along with cortical expansion. **B:** Initial treatment was cast immobilization until fracture healing. This was followed by curettage, CO₂ laser treatment, and bone grafting. At follow-up the patient's symptoms resolved and X-rays showed incorporation of the bone graft without evidence of recurrence.

tive diagnosis requires an open biopsy. The usual microscopic criteria used to determine malignancy is not as helpful in the evaluation of lesions occurring in the hands and feet, as enchondromas in these regions are typically hypercellular [6,21].

Asymptomatic lesions with typical radiographic appearance of enchondroma can be observed, and do not require a biopsy or treatment unless they are large enough to pose the threat of an impending fracture [7]. The goals of surgical treatment are: histological diagnosis, elimination of the risk of fracture, and avoidance of progressive deformity [4]. The results of curettage without bone grafting were reported as equal to those with added bone grafting and the resulting cavity may not need to be grafted [5,11]. Possible disadvantages of this approach include bone weakness and instability. One study suggested that by 4–6

weeks postoperatively, stability could be the same for bone grafted patients and those without grafting [5]. Wulle reported a recurrence rate of 10% after treating with curettage alone. We recommend grafting of the resultant cavity created by curettage particularly when the cortex is very thin after curettage, the cavity is of a sufficient size that cortical strength may be compromised, or if the lesion is complicated by a previous pathologic fracture. Also, when enchondromas are treated with curettage alone, the success or failure is directly related to the completeness with which the tumor cells are removed.

Recurrence rates of up to 15% are reported following curettage and bone grafting. Recurrence rates have decreased with adjunctive methods but at the expense of other complications. Previously reported adjunctive treatments have proven diffi-

cult to utilize in the operating room and can cause damage to adjacent normal tissue. Currently, there is a search for an effective adjunctive treatment of enchondroma that will eliminate the recurrence and is safe for the normal adjacent soft tissue. Kirby et al. have reported CO₂ lasers as effective adjunctive therapy for other bone tumors such as giant cell tumors of bone with decreased recurrence rates. CO₂ laser can decrease the recurrence rates by eliminating the 1–3mm of remaining tumor cells proven to remain after thorough curettage [24,28].

The CO₂ laser is the most commonly used laser in orthopedic surgery. In vitro and in vivo studies from our institution have concluded that CO₂ laser can be applied to cortical bone with minimal residual thermal damage. Bony changes did not exceed 200 microns and no changes were observed peripheral to the beam [9,10]. The laser dose can be adjusted to limit exposure in order to vaporize tumor cells and sterilize the margins yet limit damage to adjacent normal tissue. Rapid super-pulse mode causes less para-incisional damage and shorter healing time. CO₂ laser can be used to generate a controlled zone of tissue ablation, which makes it a useful tool for tumor margin cauterization.

The additional expense included for the use of the CO₂ laser is minimal when considering the potential cost and morbidity of recurrence. We have had no recurrences in 14 lesions treated with the CO₂ laser and therefore, the additional expense of the laser offsets the additional expense of recurrence.

Definitive conclusions regarding the influence of CO₂ laser on the treatment outcome of enchondromas can be achieved with comparative studies using large series. However, we observed in our institution improvement in our results and less recurrence rate after we began using CO₂ laser as an adjunct treatment. We investigated the functional outcomes, safety, and efficiency of CO₂ laser use as an adjunctive treatment for sterilizing the tumor bed following curettage of enchondromas prior to autologous bone grafting. At the time of this writing, there were no recurrences in the 14 lesions treated as above. Beside the laser being safe, powerful, clean, precise, efficient, and easily used, we consider it a useful adjunctive treatment to curettage and bone grafting for enchondromas of the tubular bones of the hand.

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